Age Estimation Using Pulp Chamber Volume of First Molars from Cone Beam Computed Tomography Images in Indian Population

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Abstract: *The present study established amathematical model for age estimation among the Indian population using the pulp chamber volume of first maxillary and mandibular molars with the use of CBCT images, and assessed the mathematical equation for age estimation. CBCT images of 564 maxillary first molars and 487 mandibular first molars were collected from 340 individuals to assess the mathematical model from 190 female and 150 male patients (aged 10 - 70 years). Computed tomography images were used to measure pulp chamber volumes. Age calculated using this formula was reported earlier for a Chinese population which resulted in absolute error of 8.122 and root mean square error of 5.603 between actual and estimated age for all tested teeth. The regression equation obtained for the Indian population, Age = 114.445-1.441 x Maxillary First Molar pulp chamber volume and, Age = 93.677-1.422 x Mandibular First Molar pulp chamber volume was statistically significant (p=0.000< 0.01). Hence, the pulp volume of first molars is a useful indicator of age, although correlations may vary in different populations with reasonable precision of age estimation.*

Keywords: forensic odontology, age estimation, Indianpopulation, pulp chamber volume, first molars, CBCT.

1. Introduction

Forensic medicine was redefined with the introduction of forensic odontology with tooth determinants playing a major role in age and sex determination. Age estimation, despite several methods still pose to be a never ending challenge. Gustafsonand Johanson 's[1,2] analyses, dentinal translucency and cementum annulations[7,8] are all commonly used to assess the age of an individual. Pulpal reduction caused by apposition of secondary dentin and occlusal tooth wear are used as morphometric parameters in estimating age.

The pulp chamber volume can be studied through radiographs and cross section of the tooth root.[3]Considering the distortion and two dimensional projection errors with periapical and panoramic radiographs to assess the pulp and tooth area, Cone beam computed tomography images were used in the present study. Computed tomography images were reported as the most accurate method to measure the pulp volume.[4] Gottlieb [5]correlated age changes in dentition to estimate age and apposition of secondary dentin to age was established by Bodeckar[6].

This study was conducted to evaluate the mathematical method among Indian population and to estimate the age based on the pulp chamber volume of first molars in Indian populations.

2. Materials and Method

CBCT images of 150 maxillary first molars and 150 mandibular first molars were analyzed to evaluate the mathematical model from 190 female patients and 130 male patients between the age range of 10 and 70 year. Tooth with caries, wear from erosion or attrition, dental restorations, crowns and bridges, tooth with apical bone pathologies, endodontically treated teeth and pulpal calcifications were excluded and Sound tooth with normal functional occlusion , free from traumatic manifestations were included in the study. All the CBCT images were acquired with CBCT unit NewTom VG, exposure parameters for CBCT image were 110kvp, 4.19-107.39 mAs in accordance with patient size and field of view. The field of view was selected based on clinical need which included 6cm x 6cm, 8cm x 8cm, 12cm x 8cm or 15cm x 15cm. A 3D image semiautomatic segmenting and voxel counting software ITK-SNAP 2.4,open source software was used to calculate the pulp chamber volumes. Since the first molar is a multi-rooted tooth, the roots in the 3D software were cut off to calculate the volumeof tooth pulp chamber.[9]The mathematical model was established by Ge,Zhi-pur,et al[10] by logarithmic regression analysis with age as dependent variable and pulp chamber volume as independent variable was evaluated for Indian population.

To eliminate inter examiner variability, all the measurements were done by the same examiner. To test the intra examiner reproducibility a random sample of 10 maxillary first molars and mandibular first molars were reexamined after an interval of 2weeks.

3. Statistical Analysis

The Accuracy of the measurements recorded and inter-and intra-examiner variability was determined statistically by Paired –t test. A p value of 0.05 and less was considered significant. Pulp chamber volume difference among male and female maxillary and mandibular first molars were determined by using Independent sample t test .Ap value of 0.05 and less was considered significant. The mathematical model's precision and accuracy was determined linear regression analysis

4. Results

Predicting age using the pulp channel volume:Method – Linear Regression

Entire sample (irrespective of age):

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	114.445	-1.441	0.050	-1.540	-1.342	0.669	<0.001*
Pulp Ch Vol-Mandibular First Molar	93.677	-1.422	0.059	-1.537	-1.307	0.593	<0.001*

*denotes a significant factor

Pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.001) and could explain up to 66.9% of the variation in age.

Pulp chamber volume of mandibular first molar was found to be a significant predictor of age (P<0.001) and could explain up to 59.3% of the variation in age.

Equations: (1) Age = 114.445-1.441 x Maxillary First Molar pulp volume
 (2) Age = 93.677-1.422 x Mandibular First Molar pulp volume

Age group 10-20 yrs:

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	-1.778	0.255	0.080	0.097	0.414	0.107	0.002*
Pulp Ch Vol-Mandibular First Molar	0.263	0.282	0.089	0.105	0.459	0.104	0.002*

*denotes a significant factor

In the age group of 10-20 yrs, pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.01) but it could explain only 10.7% of the variation in age.

In the age group of 10-20 yrs, pulp chamber volume of mandibular first molar was found to be a significant predictor of age (P<0.01) but it could explain only 10.4% of the variation in age.

Age group 21-30 yrs:

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	39.283	-0.237	0.030	-0.297	-0.177	0.270	<0.001*
Pulp Ch Vol-Mandibular First Molar	32.252	-0.157	0.033	-0.222	0.093	0.122	<0.001*

*denotes a significant factor

In the age group of 21-30 yrs, pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.001) but it could explain only 27.0% of the variation in age.

In the age group of 21-30 yrs, pulp chamber volume of mandibular first molar was found to be a significant predictor of age (P<0.001) but it could explain only 12.2% of the variation in age.

Age group 31-40 yrs:

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	35.015	0.006	0.190	-0.373	0.386	0.000	0.974
Pulp Ch Vol-Mandibular First Molar	30.397	0.107	0.135	-0.162	0.376	0.011	0.430

In the age group 31-40 yrs, pulp chamber volume of maxillary first molar was not found to be a significant predictor of age (P>0.05) and it could not explain any variation in age (R^2=0.000)

In the age group 31-40 yrs, pulp chamber volume of mandibular first molar was not found to be a significant predictor of age (P>0.05) and it could not explain any variation in age (R^2=0.011)

Age group 41-50 yrs:

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	77.108	-0.575	0.072	-0.740	-0.450	0.620	<0.001*
Pulp Ch Vol-Mandibular First Molar	66.277	-0.535	0.129	-0.795	-0.276	0.292	<0.001*

*denotes a significant factor

In the age group of 41-50 yrs, pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.001) and it could explain up to 62.0% of the variation in age.

In the age group of 41-50 yrs, pulp chamber volume of mandibular first molar was found to be a significant predictor of age (P<0.001) but it could explain only 29.2% of the variation in age.

Age group 51-60 yrs:

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	70.436	-0.359	0.150	-0.668	-0.051	0.169	0.024*
Pulp Ch Vol-Mandibular First Molar	63.777	-0.308	0.163	-0.641	0.025	0.113	0.069

*denotes a significant factor

In the age group of 51-60 yrs, pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.05) but it could explain only 16.9% of the variation in age.

In the age group of 51-60 yrs, pulp chamber volume of mandibular first molar was not found to be a significant predictor of age (P>0.05) and could explain only 11.3% of the variation in age.

Age group 61-70 yrs:

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	82.742	-0.498	0.195	-0.914	-0.082	0.303	0.022*
Pulp Ch Vol-Mandibular First Molar	85.351	-0.801	0.231	-1.293	-0.309	0.445	0.003*

*denotes a significant factor

In the age group of 61-70 yrs, pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.05) but it could explain only 30.3% of the variation in age.

In the age group of 61-70 yrs, pulp chamber volume of mandibular first molar was found to be a significant predictor of age (P<0.05) but it could explain only 44.5% of the variation in age.

Gender = Male (all samples):

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	131.596	-1.663	0.062	-1.786	-1.540	0.782	<0.001*
Pulp Ch Vol-Mandibular First Molar	112.136	-1.737	0.069	-1.873	-1.601	0.763	<0.001*

*denotes a significant factor

In males, the pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.001) and it could explain up to 78.2% of the variation in age.

In males, the pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.001) and it could explain up to 76.3% of the variation in age.

Gender = Female (all samples):

Predictor	Constant	β	SE of β	95% CI for β		R^2	P-Value
				Lower Bound	Upper Bound		
Pulp Ch Vol-Maxillary First Molar	120.950	-1.618	0.073	-1.762	-1.474	0.705	<0.001*
Pulp Ch Vol-Mandibular First Molar	96.044	-1.559	0.093	-1.742	-1.377	0.580	<0.001*

*denotes a significant factor

In females, the pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.001) and it could explain up to 70.5% of the variation in age.

In females, the pulp chamber volume of maxillary first molar was found to be a significant predictor of age (P<0.001) and it could explain up to 58.0% of the variation in age.

The regressions were statistically significant (p = 0.000). No significant differences were found for inter-observer (p= 0.291) and intra-observer variances (p = 0.120).

5. Discussion

This study indicates that the pulp chamber volume of maxillary and mandibular first molars as a useful tool for age predictions, but the mathematical methodvaries between different populations and was adapted: in this case for the Indian population. The most reliable age estimation methods always include the morphological characteristics of the teeth.[11]The pulp chamber volume depends on the secondary dentin deposition and assessment of pulp/tooth area ratio and pulp/tooth volume ratio are methods to indirectly quantify secondary dentine deposition. [12]Secondary dentine deposition is an ageassociated process along internal tooth surfaces which can be considered well protected against environmental influences.[13,14] An earlier report on the application of pulp/tooth area (rather than volume) ratio to estimate age concluded that the formula which had been derived for an Italian population could be applied to Indians as well.[15]secondary dentine apposition and decrease in volume over age has made its transformation an indicator of age especially in the field of forensic odontology. The periapical radiographs and the orthopantomographs used would only demonstrate the real morphological measurements restrictively.[3] The 3D images give a more accurate measure of the pulp chamber volume.[16]

CBCT is a recently developed virtual imaging modality and uses a 2D x-ray detector and a cone or pyramid shaped X-ray beam to reconstruct isotrophic high spatial resolution 3D images (32). The merits of the CBCT includes its easy accessibility and handling care , offers a multiplanar cross-sectional and 3D reconstructions through a single scan. [9] CBCT has the privilege over the microCT to provide a relatively large scanning area whereas the microCT has a confined scan area in which one extracted tooth can be scanned at a time. The radiation dose is also high in a high resolution microCt image[34].Moreover extracted teeth are needed for a microCt scan which s not acceptable for a live person and is relatively expensive and more radiation dose is required as compared to a CBCT.[16,17].

In the present study, the pulp chamber volume was measured and applied to achieve a mathematical equation and evaluate the same and use this as tool to estimate the age among the indian population. The pulp chamber volume was used as a variant in the study as, the formation of secondary dentine is directly proportional to the decrease of the pulp chamber volume of the tooth which was mainly affected by the physiological enamel wear. And the volume of the pulp chamber could be measured more accurately than the volume calculated of the tooth in total as the high image contrast between dentine and pulp chamber.[17]

The results of our study suggest that a formula devised for one population may not be applicable for another. This may be due to anthropological differences between various ethnic populations, but could also be attributed to the fact that pulp/tooth area ratios are calculated from radiographs, which are two-dimensional representations of a threedimensional object. A study was conducted to determine the accuracy of measurements of the volume of the pulp chamber calculated by CBCT against the microCT calculations. Although the microCT provided with accurate and precise measurements, the average difference between the two was very small.[18,19]

The present study showed a statistically significant difference in the volume between the genders as against many of the articles that only report the age to be estimated from the volume of the pulp chambers. Ge,Zhu-pu [10]et all reported that sex could also be estimated by the accurate measurement of the pulp chamber volume.Agematsu [20]et all regression analysis for age estimation based on pulp chamber volume using microct images of premolars and central incisors also reported age could be accurately estimated by using the estimation equation that considers sex.[27] The present study supports both Ge,Zhu and Agematsu s studies by providing evidence for sex difference distinctively. And Male group showed more stronger correlation between the pulp chamber volume and age as compared to the female group with statistically significant between maxillary and mandibular molars.(p<0.001) ,the pulp chamber volume of maxillary first molar could explain up to 78.2% of the variation in age and the mandibular molar could explain up to 76.3% of the variation in age.

Limitation of the study is that only the first molars were included and more commonly the first molars are decayed or lost constantly as this is the first tooth of the permanenet dention to erupt into the oral cavity. Since there are four first molars , loss of all four for estimation of age is very rare and hence this limitation is of little significance.

6. Conclusion

This study investigated the relationship between the age and pulp chamber volume of the multirooted first molars. Gender and age are two major variants to estimate age and its proved in the present study with a statistical significance. The mathematical model specific to the regional population is important to estimate age. CBCT is an important tool to measure the pulp chamber volume. The regression equation obtained for the Indian population was statistically significant (p=0.000< 0.01). The co efficient of determination (R2) was 0.564. Hence, the pulp volume of first molars is a useful indicator of age, although correlations may vary in different populations with reasonable precision of age estimation.

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